High Resolution Sea Ice Prediction: Coupled Processes and Prediction System Development

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Eddies are heat sources/sinks – They need to be resolved.

Average composite of latent and sensible heat flux in anticyclonic and cyclonic eddies.

“In strongly energetic regions, eddies explain up to 20% of the total variance in the surface turbulent heat fluxes with averaged anomalies of +/- 10-20 w/m$^2$.”


Eddies significantly modify air-sea interaction (both heat and momentum)
Impact of horizontal Grid Resolution on Gulf Stream Separation and Eddy generation, both surface and subsurface

Eddy resolving resolution is necessary both at the surface and at depth

From Hurlburt and Hogan (2008, DAO)
System Components

HYCOM (ocean) DA: NCODA

CICE (ice) DA: NCODA

NAVGEM-LSM (land-surface) DA: LIS

NAVGEM (atmosphere) DA: NAVDAS-AR

WW3 (waves) DA: NCODA

NAAPS (aerosol) DA: NAVDAS-AOD

All components pass through a mediator
Results from Operational GOFS 3.0 (1/12° HYCOM with NCODA Data Assimilation)

SSH date: Mar 23, 2007 90.2

Global SSH on 23 Mar 2007
Gray areas are ice covered

• Horizontal grid: 1/12° equatorial resolution
  • 4500 x 3298 grid points, ~6.5 km spacing on average, ~3.5 km at pole
• Vertical coordinate surfaces: 32 for $\sigma_2^*$
• KPP mixed layer model
• Thermodynamic (energy loan) sea-ice model
• Surface forcing: FNMOC NAVGEM 1.2
• Monthly river runoff (986 rivers)

GOFS 3.1 to be operational Oct. 2015
HYCOM Assimilation: NCODA

Raw Obs

Ocean Data QC

3DVar

HYCOM

SST: NOAA (GAC, LAC), METOP (GAC, LAC), GOES, MSG, AATSR, AMSR-E, Ship/Buoy Profile Temp/Salt: XBT, CTD, Argo Float, Fixed/Drifting Buoy
SSH: Jason-2, Altika, In situ
Sea Ice: SSM/I, SSMIS
Glider: Slocum, Sea-glider, Spray (T,S,U,V)

Navy Coupled Ocean Data Assimilation: operational at Navy production centers (NAVOCEANO, FNMOC)

3DVar - analysis of 5 ocean variables: temperature, salinity, geopotential, velocity (u,v)

Adaptive Sampling Guidance

Forecast Fields Prediction Errors

First Guess

QC Data Cut

Incremental Update Cycle
Navy ESPC

Initial Operational Capability 2018

- Not yet fully defined: initial working definition is NavESPC should be running in pre-operational mode at Navy DSRC under EOM with FNMOC-NAVO-DSRC cycling (uncoupled) DA and producing “prototype products”.

<table>
<thead>
<tr>
<th>Forecast</th>
<th>Time Scale, Frequency</th>
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<td>0-16 days, Daily</td>
<td>T681 (13 km) 100 levels</td>
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¹Vertical resolution of HYCOM still to be determined.

²Because the operational centers don’t get significantly more time on any one specific day of the week, the ensembles need to be broken up across the week. Run four ensemble members each day of the week.
Increased surface stress associated with westerly wind bursts acts to boost the IEC, which in turn impacts air-sea fluxes in HYCOM (left). Feedbacks are nonnegligible, with surface latent heat flux perturbations of up to 10 W/m² (right).
The sensitivity of MJO predictive skill in the coupled system to modifications of the NAVGEM physics as compared to air-sea interaction is a topic of ongoing research.
Impact of Coupled ocean-Ice-Atmosphere in Polar Regions

2 m air temperature bias of 120 hour forecasts for May 2014

Coupled system has significantly less bias
Ocean Model Scorecard Example

ESPC Forecast vs. GOFS Operational Analysis

Score_model(i) = 1 – (Error_model(i) / Maximum_error(i))
Total_score_model = mean (Score_model(i))

Luis Zamudio, NRL-SSC
ESPC Forecast SST vs. Operational SST Analysis

Coupled (ESPC) monthly mean forecast vs. non-coupled (GOFS) monthly mean analysis

ESPC minus HYCOM - SST for 2014 10

Difference after 1-month forecast

Warm bias (false El Nino)

ESPC minus HYCOM - SST for 2015 02

Difference after 5-month forecast
Preliminary Results from 180 day Coupled Simulation

- The Navy ESPC coupled system has been run for 180 days starting from uncoupled initial states on 31 March 2014
- Coupled model develops a strong El Nino (warm bias) when no El Nino occurred
  - Most forecasts that year developed an El Nino
  - May have a warm bias in ocean IC
  - NAVGEM winds may be too weak
  - Land biases reflect analyses performed at 0000Z
- Still have problems with
  - Double ITCZ
  - Tropical cyclogenesis
  - Rainfall over Indonesian
- Improvements
  - Asian Monsoon
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- Deterministic: ~ 6 hours on ~9000 cores
- Seasonal Ensemble ~18 hours on ~2200 cores
- So, ~9000 cores ~24 hrs/day likely enough for both (6 hrs for deterministic, 18 hrs for 4x ens)